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Report No. 165

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A FURTHER INVESTIGATION OF THE INFLUENCE OF WHOLE-BODY VIBRATION AND NOISE ON TREMOR AND VISUAL ACUITY

by

M. Loeb
with the technical assistance of
W. M. Bass, E. E. Roberts and M. L. Samuelsen

from

Psychology Department

Submitted

22 October 1954

19 pp & ii 6 illus.

Abstract:

Subjects were exposed to two amplitudes of vibration at three different frequencies, to 115-db broad-band noise, and to a control condition. Differential effects on visual acuity, manual tremor, and aiming tremor were found during exposure to different frequencies and intensities of vibration. Noise had no apparent differential effects. There were no significant differences in the experimental measures after vibration.

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REPORT NO. 165

A FURTHER INVESTIGATION OF THE INFLUENCE OF WHOLE-BODY VIBRATION AND NOISE ON TREMOR AND VISUAL ACUITY*

by

M. Loeb, Psychologist
with the technical assistance of
William M. Bass, Psychologist, Ernest E. Roberts, Sgt
and Manford L. Samuelsen, Cpl

from

PSYCHOLOGY DEPARTMENT
ARMY MEDICAL RESEARCH LABORATORY
FORT KNOX, KENTUCKY
24 January 1955

*Subtask under Psychophysiological Studies, AMRL Project No. 6-001, Subtask S-3, Noise and Vibration Problems.

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ABSTRACT

A FURTHER INVESTIGATION OF THE INFLUENCE OF WHOLE-BODY VIBRATION AND NOISE ON TREMOR AND VISUAL ACUITY

OBJECT

To determine the nature and extent of changes in visual acuity, manual tremor, and aiming tremor under the influence of intense noise and/or vibration.

RESULTS AND CONCLUSIONS

Differential effects on performance were obtained during exposure to different intensities and frequencies of vibration. Performance was most affected by the lower frequencies of vibration. The most clear-cut differential effects between different amplitudes were obtained at the lowest frequency (10 cps). No post-vibration effects were noticeable after 150 minutes of vibration, and no variation in performance could be attributed to noise, either during or after exposure.

RECOMMENDATIONS

The results of this study indicate that visual acuity is impaired and both manual tremor and aiming tremor are increased during vibration. Performance or tasks requiring hand-eye coordination, such as driving in narrow limits or tracking a target, might also be impaired. Wherever possible, vibration in motorized vehicles should be reduced.

[illegible] October 1954 by:
M. Loeb, Psychologist
with the technical assistance of
William M. Bass, Psychologist
Ernest E. Roberts, Sgt
Manford L. Samuelsen, Cpl

APPROVED:
RAY G. DAGGS
Director of Research

APPROVED:
WILLIAM W. COX
Lt Colonel, MC
Commanding

FURTHER INVESTIGATION OF THE INFLUENCE OF WHOLE-BODY VIBRATION AND NOISE ON TREMOR AND VISUAL ACUITY

I. INTRODUCTION

In a previous experiment (8), a number of psychophysiological measures were tested as possible indices of disturbance during or after exposure to whole-body vibration and noise. Most of these measures, including tests of tapping speed, mirror tracing, simple and choice reaction time with and without warning, strength of grip, blood pressure, and pulse rate, were little affected by noise or vibration. Two measures, however, varied considerably with the experimental conditions. Visual acuity was noticeably impaired in proportion to the amplitude of the vibration. Tremor, in a supported hand, increased significantly under heavy vibration but not under light vibration.

It has been known for some time that vibration produces an impairment of visual acuity. Coermann (1, 2) and Stevens (11) believed it to be a purely mechanical effect. Coermann reported that the extent of impairment at any frequency tends to be directly proportional to the amplitude of the vibration. He also stated that at any given amplitude of head vibration there are apparent resonance points, or peaks of impairment, at various frequencies. Most of his subjects showed two such peaks, one between 25 and 45 cps and the other between 60 and 90 cps, the latter being most pronounced (1). In another paper Coermann suggested that there is only one such resonance peak, generally between 50 and 80 cps (2). Crook and his associates have demonstrated that vibration of the visual field produces an impairment of visual acuity (3). This impairment is smaller than that produced by a comparable vibration of the body or head, perhaps due to the resonance phenomenon described by Coermann.

A number of investigators have studied the effects of noise on visual acuity or on the visual contrast threshold but they do not agree on the effects produced (7). Some report a general enhancement of visual acuity (4). Others report an enhancement of visual acuity for black objects on a white field and an impairment for white objects on a black field (6). A previous investigation (8) by the present author demonstrated no such effects.

Coermann found an increased manual tremor under light vibration and a somewhat smaller increase under heavy vibra-

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Visual Acuity

As in the previous experiment (8), the stimulus object for visual acuity measurements was the projected image of a Ronchi ruling placed 10 feet from a subject and seen through a circular aperture 2.2 centimeters in diameter. The image was 1.63 foot-lamberts in intensity and consisted of alternate black and white bars equal in width. The coarseness of the grating as well as the orientation of the bars could be altered by the experimenter.

The test object was first projected so that it was easily visible to the subject who was told to indicate with an electric signaling device the directions of the lines. Four orientations of the grating were used: horizontal, vertical, and two diagonal positions. At any given coarseness each of these orientations was presented twice within a random order. The coarseness of the grating was progressively reduced until the subject reported that he could no longer see bars and spaces. At this point he was still required to guess the orientation of the lines of the grating. The last setting of the grating at which the subject made two correct identifications of the horizontal orientation was taken as his threshold. Settings were read directly from the scale attached to the Clason projector. The scale is based on decimal acuity. (Decimal acuity readings are clinical measurements converted to decimals. Thus, 20/20 vision corresponds to a decimal acuity of 1.00; 20/40 to an acuity of 0.50, etc.). The subject's chances of guessing correctly the orientation of the grating at any given setting was only one in sixteen, and at two consecutive settings only one in 256.

B. Conditions

1. Vibration

The source of vibration has been described in a previous report (8). Essentially, it consisted of a seat-equipped platform which vibrated sinusoidally in a vertical plane at frequencies ranging from 5 to 40 cps at peak-to-peak amplitudes up to one-half inch. In a preliminary experiment amplitude thresholds of immediate annoyance and endurability were determined with 13 laboratory personnel at frequencies of 15, 25, and 35 cps. The thresholds are discussed later in the report. It seemed desirable to establish two levels of vibration (a "light" and "heavy" level), varying in degree of disturbance to the subject, and not likely to be injurious over a 2 1/2 hour period. The "light" level was established at the mean annoyance threshold, while the heavy level represented the arithmetic mean of annoyance and endurability thresholds. The "light" levels thus obtained gave root mean square (rms) values of 0.024 inch at 15 cps, 0.012 inch at 25 cps; and 0.011 inch at 35 cps. The "heavy" levels (rms) were 0.04 inch at 15 cps; 0.020 inch at 25 cps; and 0.019 inch at 35 cps. The "light" levels were picked as levels which would be at least mildly disturbing to the subject. Since the thresholds were secured at minimum exposure, it seemed doubtful that subjects would endure the endurable or "barely tolerable" levels for an extended period or that such exposure would be advisable. The mean of the annoyance and tolerance threshold was therefore established as a more than annoying, or "heavy" level. One-third of the subjects were vibrated at 15 cps, one-third at 25 cps, and one-third at 35 cps. All subjects were exposed to both the "light" and "heavy" levels of vibration at their respective frequencies.

2. Noise

"Light" levels of vibration previously described produced no more than 95 decibels of noise and the "heavy" levels produced no more than 105 decibels of noise. In the noise condition of this study a recording of the platform noise was played at 115 decibels. (This is a change from the experiment described previously (8) in which a 98-decibel noise source was used.) The recording was made on an Ampex recorder and played through a Bogen amplifier and an Altec-Lansing coaxial speaker. The platform noise had a relatively wide frequency spectrum concentrated principally below 1000 cps. The measurement of 115 decibels was taken at the position of the head of the subject in a free field with an H. H. Scott sound level meter.

3. Control

In the control conditions there was no vibration and no noise except ambient noise which varied between 60 and 65 decibels.

C. Design

Table 1 lists the sequences of test conditions used in the study. There were 24 possible condition sequences and 6 possible test sequences - a total of 144 test conditions. Although the same combinations for each of three vibration frequencies would have been desirable, a total of 432 subjects and an inordinate amount of time would have been required for complete counterbalancing. In practice, 1 test sequence was paired randomly with each of 6 condition sequences. It was assumed that the order effect from the second to the third condition in a sequence (overnight) is less than that from the first to the second or the third to the fourth (within a day). The sequences

...were selected counterbalance order effects within a given...

TABLE 1

EXPERIMENTAL SEQUENCES

SEQUENCE OF CONDITIONS*		SEQUENCE OF TESTS*
Day 1	Day 2	
CH**	NL**	AMV*
LN	HC	AVM
CN	LH	VMA
HL	NC	VAM
CL	HN	MVA
NH	LC	MAV

*Each of the above 6 combinations of condition sequences and test sequence was utilized for one subject in each frequency group. Since there were three frequency groups (at 15, 25, and 35 cps), a total of 18 combinations of sequences and frequencies was utilized. A random order of these 18 was established and each subject was assigned to a combination in order of arrival at the laboratory.

**C = Control; H = Heavy Vibration; L = Light Vibration; N = Noise; A = Aiming Tremor; M = Manual Tremor; V = Visual Acuity.

Three successive repetitions of each test constituted an experimental trial. Trial A was administered prior to exposure to a condition; Trial B at the beginning of exposure; Trial C after 40 minutes of exposure; Trial D after 80 minutes of exposure; Trial E 2 hours after the beginning; and Trial F immediately after cessation of exposure. The average time per trial was 20 minutes, and all exposures were for 2 1/2 hours. It was felt that if 4 trials were spaced rather evenly throughout exposure, temporal changes during exposure would become apparent.

D. Subjects

The 18 subjects were trainees from the Armored Center at Fort Knox. They were between 18 and 25 years of age, in good physical condition, and within the normal range of intelligence. All appeared to understand the instructions.

III. RESULTS

A. Thresholds

Table 2 summarizes threshold data obtained for 13 professional and technical members of the laboratory staff. Standard deviations and standard errors of means are included only as a matter of general information. They cannot be used to test significance of differences since all means were obtained for the same 13 people

... es given are amplitudes of platform vibration. The ... of seat vibration are somewhat smaller than the stated am- tudes due to lack of rigidity of the tank bucket seat. It is notew... that thresholds were considerably lowered between 15 and 25 cps. but were almost the same at 25 and 35 cps.

TABLE 2

R.M.S.* THRESHOLDS OF 'ANNOYING' AND 'BARELY TOLERABLE' VIBRATION

(Figures are inches of amplitude of platform vibration)

	15 cps		25 cps		35 cps	
	A*	BT*	A*	BT*	A*	BT*
M	.024"	.035	.012	.026	.011	.027
σ	.015"	.021	.009	.017	.008	.019
σ_M	.0013"	.0017	.0008	.0014	.0007	.0010

*R.M.S. = Root Mean Square.

A = 'Annoyance' Threshold.

BT = 'Barely Tolerable' or 'Endurability' Threshold.

B. Visual Acuity

Figure 1 and Table 3 present the thresholds of visual acuity before, during, and after exposure to the experimental conditions. Table 4 indicates the significance of the changes. Variances due to experimental trial and experimental conditions were significant beyond the 0.01 level, while interactions of these variables and interactions involving the frequency variables were generally significant. A further analysis* indicated that during exposure either to light or heavy vibration visual acuity was impaired significantly. The difference in impairment between light and heavy levels was considerable and consistent on repeated trials at 15 cps. At 25 and 35 cps, differences were smaller and not consistent. Impairments were considerably larger at 15 cps.

There were no systematic or significant differences between trials during exposure to the experimental conditions, nor were there any apparent changes resulting from exposure to any experimental condition. The noise employed in this experiment did not significantly affect visual acuity.

* Available on request.

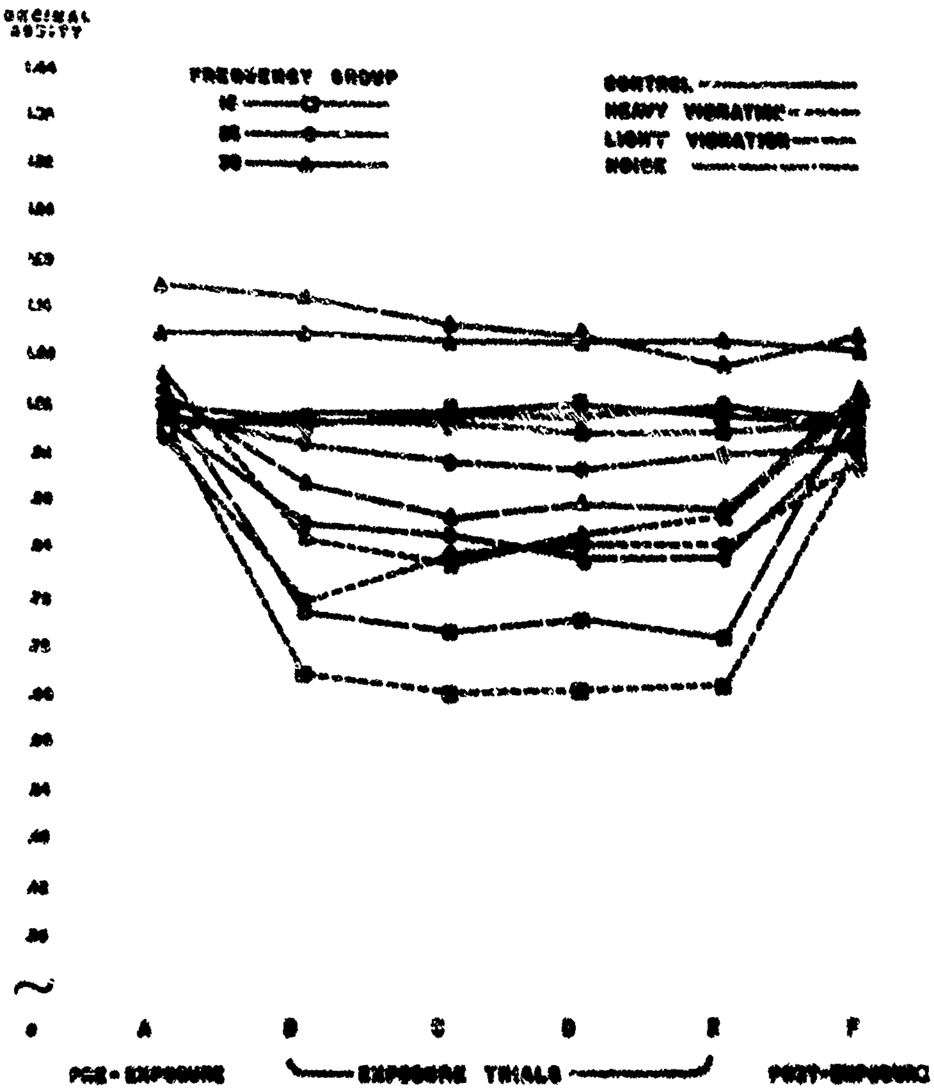

Fig.1 EFFECTS OF NOISE AND VIBRATION ON VISUAL ACUITY

TABLE 3

EFFECT OF NOISE AND VIBRATION ON VISUAL ACUITY

Means and Ranges of Visual Acuity*												
	Exposure Conditions											
	Control						Light Vibration					
Frequency (cps)	Pre-Exposure		Exposure		Post-Exposure		Pre-Exposure		Exposure		Post-Exposure	
	M	R	M	R	M	R	M	R	M	R	M	R
15	1.00	0.34	1.02	0.37	1.02	0.33	1.05	0.21	0.76	0.17	1.04	0.[illegible]
25	1.01	0.45	1.02	0.46	1.02	0.46	1.01	0.28	0.86	0.42	1.01	0.28
35	1.12	0.13	1.11	0.25	1.11	0.18	1.06	0.18	0.91	0.27	1.04	0.25
	Heavy Vibration						Noise					
Frequency (cps)	Pre-Exposure		Exposure		Post-Exposure		Pre-Exposure		Exposure		Post Exposure	
15	1.02	0.14	0.98	0.28	1.01	0.38	1.04	0.23	1.02	0.27	1.02	0.27
25	1.09	0.23	0.84	0.28	1.00	0.22	1.01	0.20	0.97	0.58	0.98	0.22
35	1.07	0.13	0.97	[illegible]	[illegible]	[illegible]	1.18	0.34	1.13	0.37	1.13	0.18

* Decimal Units

TABLE 4

EFFECT OF NOISE AND VIBRATION ON VISUAL ACUITY

Summary of Analysis of Variance					
Terms	D.F.	M.S.	F	ET	Sign
A. Subjects in same frequency group	18	.4396			
B. Frequencies	2	1.8[illegible]	3.42	A	--
C. Subjects	17				
D. Conditions	3	2.7208	40.00	AD	<.01
E. Trials	5	.0240	96.83	AE	<.01
DE	15	.2077	40.02	ADE	<.01
BD	6	.1806	2.37	AD	<.05
BE	10	.0080	4.36	AE	<.01
BDE	30	.1707	34.05	ADE	<.01
AD	45	.0640	10.78	ADE	<.01
AE	75	.0077	1.31	ADE	<.05
ADE	225	.0051	0.50	W.V.*	<.01
* Within Variance	864	.0006			

C. Manual Tremor

Figure 2 and Table 5 present means of manual tremor before, during, and after exposure to the experimental conditions.

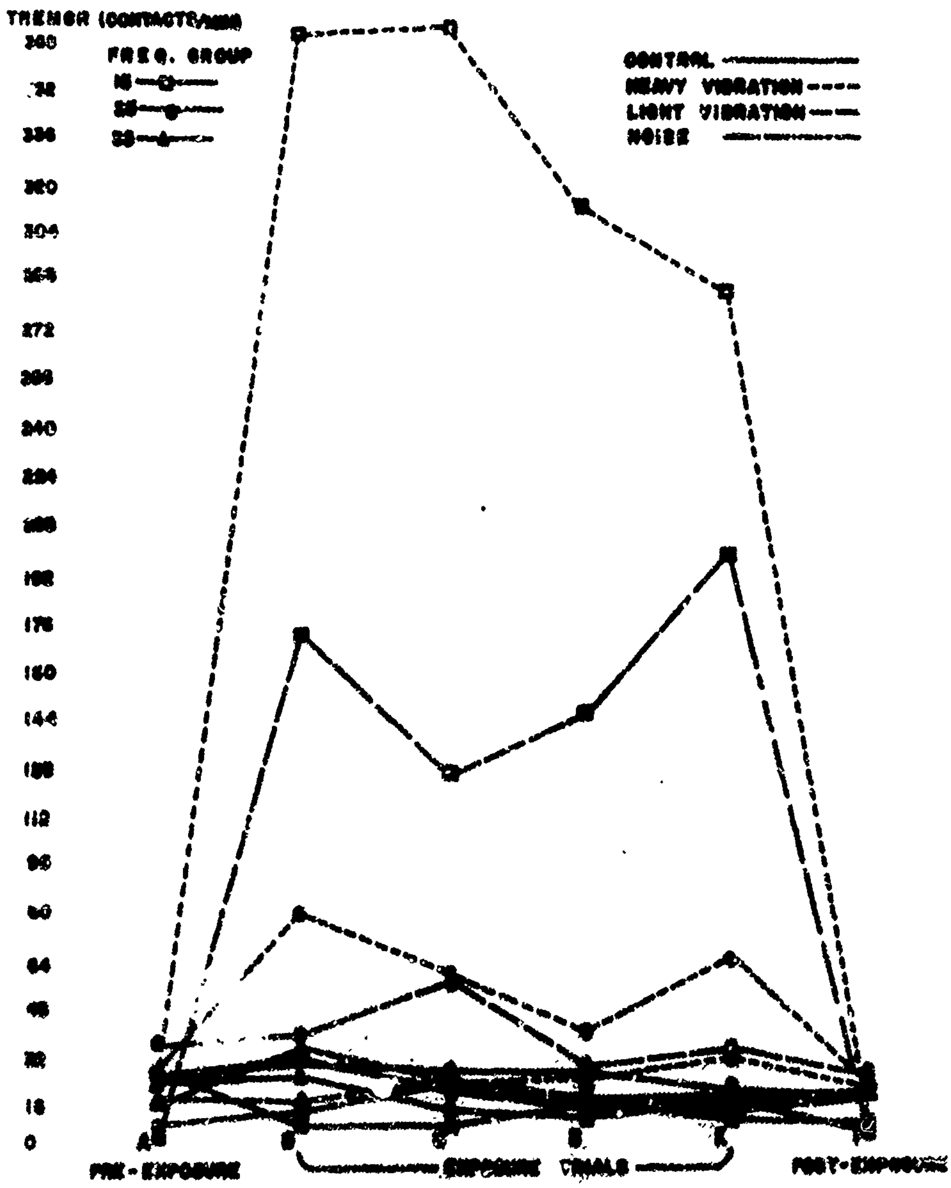

Fig.2 EFFECTS OF NOISE AND VIBRATION ON MANUAL TREMOR

TABLE 5

EFFECTS OF NOISE AND VIBRATION ON MANUAL TREMOR IN A SUPPORTED HAND

Means and Ranges of Manual Tremor*												
Exposure Conditions												
	Control						Light Vibration					
Vibration Frequency	Pre-Exposure		Exposure		Post-Exposure		Pre-Exposure		Exposure		Post-Exposure	
(cps)	M	R	M	R	M	R	M	R	M	R	M	R
15	10.7	25.0	3.5	10.0	3.1	5.0	3.8	10.7	54.1	225.0	4.1	5
25	9.4	15.0	8.7	22.3	5.4	6.7	12.1	27.0	13.8	60.0	7.2	13.3
35	6.2	15.3	5.5	23.3	2.4	7.0	5.3	18.7	6.5	24.7	2.9	7.7
	Heavy Vibration						Noise					
Vibration Frequency	Pre-Exposure		Exposure		Post-Exposure		Pre-Exposure		Exposure		Post-Exposure	
(cps)	M	R	M	R	M	R	M	R	M	R	M	R
15	18.3	38.0	112.4	365.3	4.9	8.7	5.4	15.7	8.0	21.0	3.9	4.3
25	13.5	20.3	20.6	104.7	8.8	8.7	9.6	23.7	7.4	24.0	3.4	12.7
35	5.6	17.7	9.4	41.7	3.8	18.7	6.6	17.0	5.9	26.3	4.4	7.[illegible]

* Contacts in a 60 second period.

TABLE 6

EFFECTS OF NOISE AND VIBRATION ON MANUAL TREMOR IN A SUPPORTED HAND

Summary of Analysis of Variance					
Terms	D.F.	M.S.	F.	ET	Sign.
A. Subjects in Same Frequency Groups	15	24,815			
B. Frequencies	2	73,686	3.04	A	--
C. Subjects	17				
D. Conditions	3	87,418	9.03	AD	<.01
E. Trials	5	13,902	5.56	AE	<.01
DE	15	5,488	4.18	ADE	<.01
BD	6	38,185	3.88	AD	<.01
BE	10	8,122	3.47	AE	<.01
BDE	30	3,965	3.06	ADE	<.01
AD	45	9,585	7.94	ADE	<.01
AE	75	2,341	1.80	ADE	<.01
ADE	225	1,298	4.84	W.V.*	<.01
Within Variance	864	263			

6 summarizes the analysis of variance. Variance between ...s, between experimental conditions, the interaction of these variables, and the interactions of frequency with these variables were all significant beyond the 0.01 level. Further treatment of the data* revealed that noise did not significantly alter manual tremor. The vibration means did not differ significantly from the control, nor was there a significant difference between trials during exposure to vibration. Manual tremor increased significantly while undergoing both vibrating conditions. The significant interaction of frequency and experimental condition is shown quite clearly in Figure 2. It is apparent that increases in tremor were considerably greater at 15 cps than at higher frequencies, and that the difference in impairment between "light" and "heavy" levels was larger and more consistent from trial to trial at 15 cps. Differences between trials during exposure were not significant.

D. Aiming Tremor

1. Comparison of Tremor Scores in Different Directions

It was originally planned that the four tremor scores would be combined into one. Upon inspection they appeared to be representative of different populations. Sign tests indicated the tremor to the right did not differ appreciably from the tremor to the left. The tremor upward exceeded the tremor to the right, and tremor downward exceeded tremor upward (both beyond the .01 level). Consequently, the four measures were not pooled.

2. Effects of Noise and Vibration

Figures 3, 4, 5, and 6 represent the variation of different components of aiming tremor with the experimental conditions. Tables 7 and 8 list the means and ranges of vertical aiming tremor before, during, and after exposure, and summarizes the analysis of variance for that measure. Downward tremor was selected for this analysis since it seemed most sensitive to vibration effects. It is apparent from Table 8 and from extensions of the analysis** that noise did not affect aiming tremor, but that tremor

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*Available on request.

** ... request.

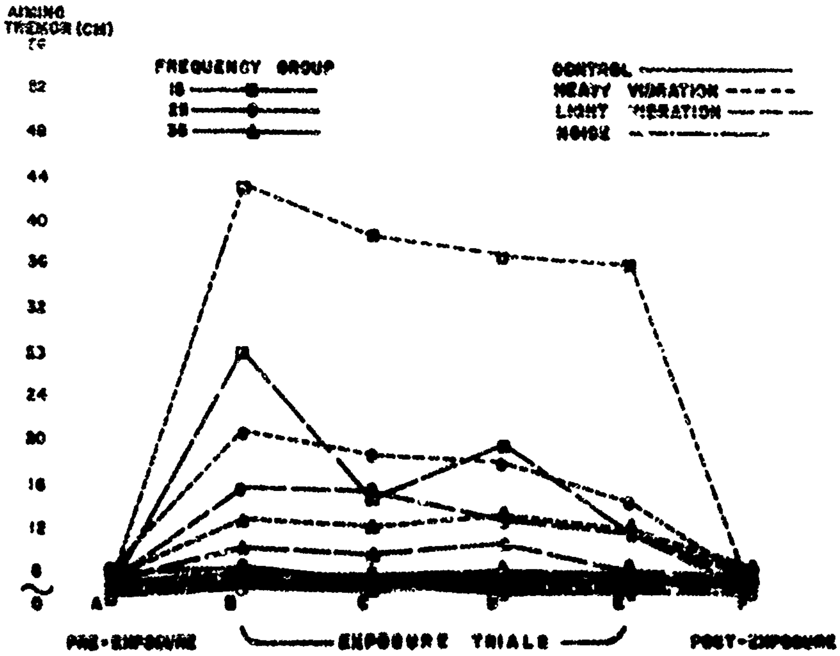

Fig. 8 EFFECTS OF NOISE AND VIBRATION ON AIMING TREMOR TO THE LEFT

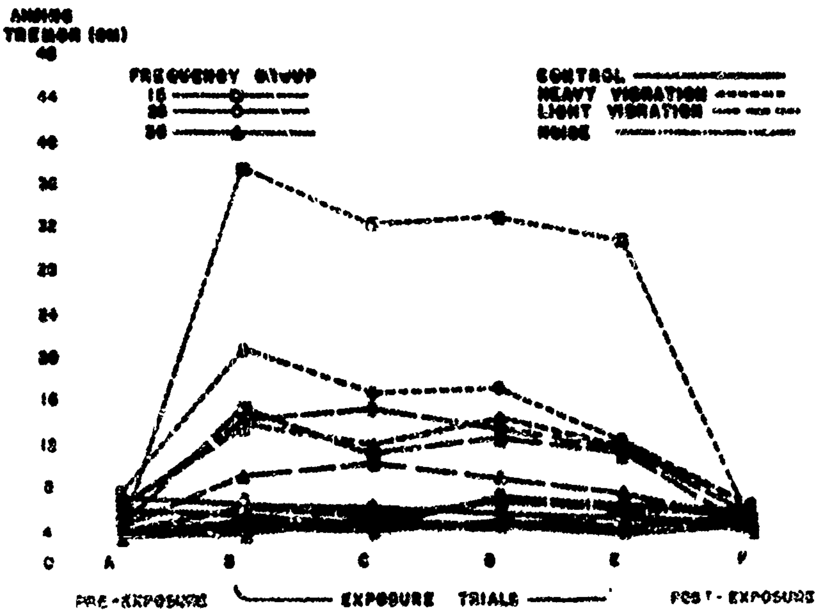

Fig. 9 EFFECTS OF NOISE AND VIBRATION ON AIMING TREMOR TO THE RIGHT

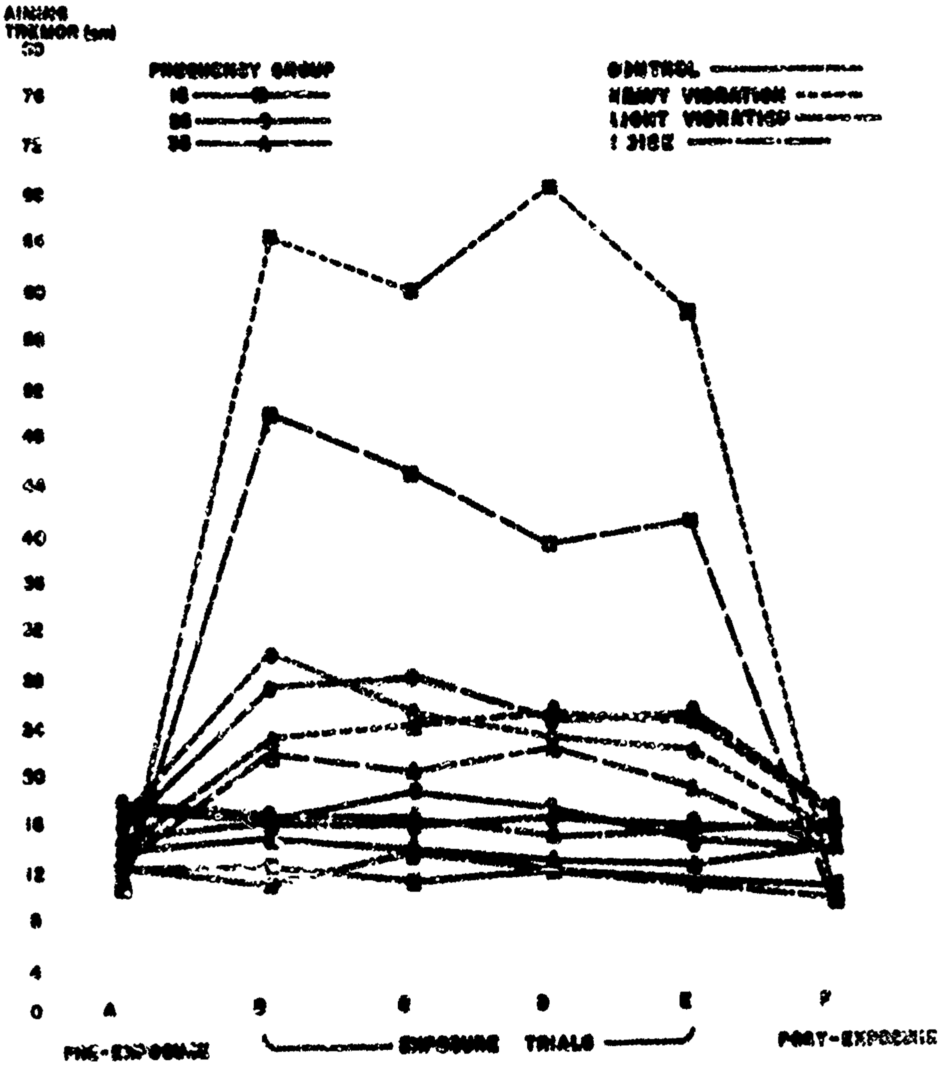

Fig.6 EFFECTS OF NOISE AND VIBRATION ON DOWNWARD AIMING TREMOR

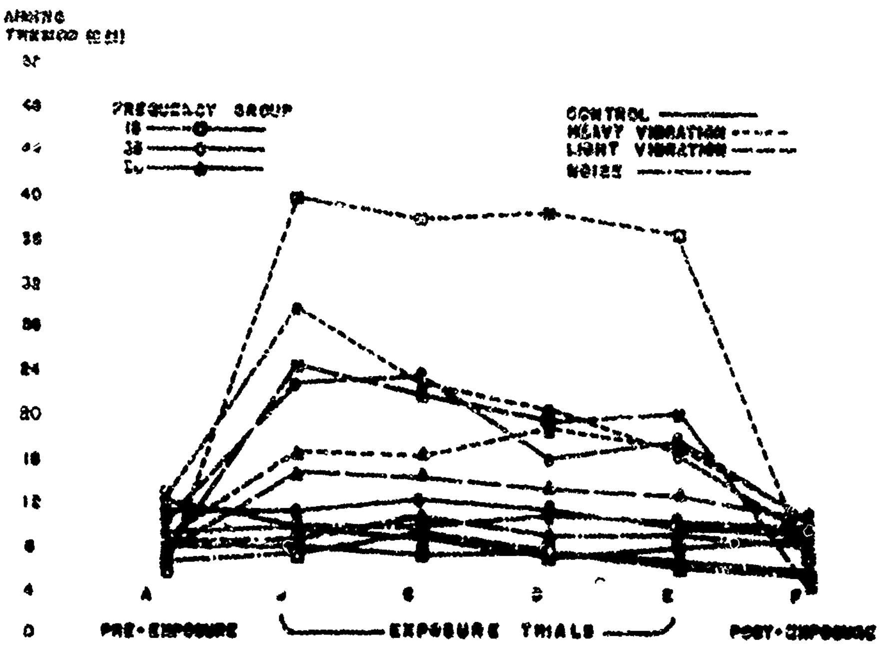

Fig. 6 EFFECTS OF NOISE AND VIBRATION ON UPWARD AIMING TREMOR

TABLE 7

EFFECTS OF NOISE AND VIBRATION ON DOWNWARD AIMING TREMOR

Means and Ranges of Downward Aiming Tremor°												
Exposure Conditions												
	Control						Light Vibration					
Frequency (cps)	Pre-Exposure		Exposure		Post-Exposure		Pre-Exposure		Exposure		Post-Exposure	
	M	R	M	R	M	R	M	R	M	R	M	R
15	4.2	3.0	4.0	3.9	2.8	3.7	3.8	2.7	14.8	12.5	2.6	3.3
25	5.8	3.7	5.7	6.0	4.6	3.1	5.3	4.0	8.8	9.2	5.6	3.8
35	4.8	5.0	4.6	5.5	4.7	[illegible]	4.5	3.8	7.1	5.7	4.5	4.2
	Heavy Vibration						Noise					
Frequency (cps)	Pre-Exposure		Exposure		Post-Exposure		Pre-Exposure		Exposure		Post-Exposure	
	M	R	M	R	M	R	M	R	M	R	M	R
15	3.8	3.7	21.0	18.8	3.5	3.7	4.3	2.8	[illegible]	5.3	3.5	2.4
25	3.8	4.3	[illegible]	13.6	4.8	5.7	6.0	3.8	8.4	3.0	5.2	[illegible]
35	4.7	4.4	8.2	8.3	5.4	5.6	5.2	5.0	5.2	6.2	4.9	[illegible]

... second period.

TABLE 6

EFFECTS OF NOISE AND VIBRATION ON DOWNWARD AIMING TREMOR

Summary of Analysis of Variance					
Terms	D.F.	M.S.	F	ET	Sign
A. Subjects in Same Frequency Group	15	106.70			
B. Frequencies	2	881.40	5.35	A	<.05
C. Subjects	17				
D. Conditions	3	2,173.78	79.52	AD	<.01
E. Trials	5	712.84	70.18	AE	<.01
DE	15	234.04	32.80	ADE	<.01
BD	6	725.40	26.14	AD	<.01
BE	10	510.91	23.42	AE	<.01
BDE	30	83.74	11.83	ADE	<.01
AD	45	27.78	3.[illegible]	ADE	<.01
AE	75	[illegible].00	1.[illegible]	ADE	--
ADE	225	7.50	2.81	W*	<.01
* Within Variance	[illegible]	2.76			
Total Variance	[illegible]				

was increased significantly during vibration. As in the case of the other measures, increase in tremor was greatest at the 15 cps, and the difference in increase between the "light" and "heavy" levels was greatest and most consistent from trial to trial at this frequency.

IV. DISCUSSION

A. Tolerance Thresholds

It is not known whether values of annoyance and tolerance previously reported by Reiher and Meister (10) represent root mean squares or peak-to-peak amplitudes. Even if damping is taken into consideration by multiplying all values by 2, the values obtained are obviously higher than the Reiher and Meister thresholds or those of other experimenters discussed by Janeway (5). Moreover, the "heavy" levels are considerably above the Reiher and Meister tolerance values. The threshold at 15 cps was lower than that reported by Müller (9).*

* Tolerance values obtained by Reiher and Meister were approximately .02", .007", and .002" at 15, 25, and 35 cps, respectively. Muller reported a threshold of 0.28 at 15 cps.

The reason for these discrepancies is not clear. Pe... ...e of the subjects may account for the differences in the ...ferent experiments. The practice of using "tolerance" or "annoyance" thresholds as limiting values of vehicle vibration is questionable. Thresholds differ from one experiment to another, probably as a result of the morale and motivation of the subjects, wording of instruction, and other undetermined variables. Moreover, even if subjective thresholds were consistent and stable, there would be no logical reason to assume that such a threshold represents a limit of safe vibration. Certainly, some personnel (e.g., drop-forge workers, gun crews, etc.), while not aware of possible effects, are willing to work in noisy environments which may eventually damage their hearing.

B. Impairments

It appears that visual acuity is impaired and both manual tremor and aiming tremor are increased during vibration. There was a tendency for these effects to increase with amplitude but the tendency was not consistent at higher frequencies.

It might be objected that the "heavy" and "light" amplitudes at 35 cps were much less than the corresponding levels at 15 cps. Therefore, if amplitude determined the observed decrement, it might be expected that the higher frequencies would produce less effect at a given subjective level. "Light" levels were 0.024 inch rms, 0.012 inch, and 0.011 inch at 15, 25, and 35 cps, respectively; corresponding "heavy" values were 0.[illegible]4 inch, 0.020 inch, and 0.019 inch.) However, the fact that the excursion was half as great at 35 cps should be compensated for by the fact that the movements occurred one and three-quarters times as often. Moreover, the effects at 35 cps were obviously smaller than those at 25 cps, even though the amplitudes were approximately the same.

Coermann and others have pointed out (1, 2, 9) that transmission of vibration is appreciably reduced at higher frequencies. Since the parts affected (e.g., head, eyeballs, hands, and arms) are at different distances from the vibration source and probably differ considerably in natural frequency, extent of impairment would differ according to the nature of the task (as appeared to be the case in the present study).

If only mechanical factors were operative, it might be ex... ...ted that higher amplitudes would produce consistently more decre... than lower amplitudes at a given frequency. This was not

... regarding impairment of visual acuity at ... case in aiming tremor at 25 or 35 cps. It is possible ... higher frequencies the higher amplitudes brought compensat... nisms into play, while the lower amplitudes did not. (This is in accord with Coermann's interpretation.) On the other hand, the 15 cps vibration, being considerably less attenuated than vibrations at 25 and 35 cps, may have been so large at the higher amplitudes that compensation was not feasible.

An alternative explanation might be that inconsistent differential effects between amplitudes at a given frequency might reflect changes in body position or body attitude (slumped or upright, relaxed or tense) which would alter the attenuation characteristics. This latter interpretation would not explain why differences between levels were so much more pronounced and consistent at 15 cps than at 25 and 35 cps. A future experiment might minimize this factor by deliberately controlling body attitude.

Statements as to differential effects at various frequencies and interpretations of such effects should await the results of more extensive studies, employing larger numbers of subjects. Results of this study do not entirely agree with Coermann's. He reports a greater tremor at low amplitudes than at high amplitudes at a given frequency and implies that this effect is due to compensation on the part of the subject. It is not clear, however, whether he is talking about tremor during vibration or after vibration. In the frequency range in which the experiment was performed, his after-effects were nil, as they were in this study. Results at the higher frequencies in this study (close to Coermann's lower frequencies) suggest that some sort of compensation on the part of the subject may have been operating.

V. SUMMARY

Mean "annoyance" and "tolerance" levels under vibration were obtained for 13 laboratory personnel at 15, 25, and 35 cps sinusoidal vibrations. Arbitrary "light" levels were set at the mean annoyance levels, and "heavy" levels were set at values intermediate between the annoyance and tolerance levels. All 18 subjects were exposed to both low and high levels of vibration; 6 at 15 cps; 6 at 25 cps; and 6 at 35 cps. The 18 subjects were tested for visual acuity, tremor in a supported hand, and aiming tremor. Tests were performed once before exposure, four times during exposure, and once after exposure to each vibration condition, a 115-decibel noise condition, and a control condition. Generally speaking, during ... visual acuity was impaired and manual tremor and a...

... tor were increased while noise had no effect. Effects w... pronounced at 15 cps than at the higher frequencies. Clear ... differential effects between "light" and "heavy" vibration were pre... only at lower frequencies. Possible explanations for the latter result were discussed.

VI. RECOMMENDATIONS

Extensive curves for visual acuity, aiming tremor, and manual tremor during vibration should be obtained, employing a greater variety of frequencies and amplitudes and a greater number of subjects in various body positions and attitudes.

When hand-eye coordination is important (e.g., in aiming a gun), care should be taken to reduce vibration, especially at lower frequencies.

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